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# Characteristics of dietary intakes including NOVA foods among pre-adolescents living in urban Kuala Lumpur – Findings from the PREBONE-Kids study

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## ABSTRACT

**Introduction:** Evidence showed considerable variability of health risk factors within different socioeconomic groups. This study aimed to characterise dietary intakes by total household income among a sample of Malaysian pre-adolescents in urban Kuala Lumpur. **Methods:** Baseline data of 243 healthy, pre-adolescent children between 9 and 11 years old including socio-demographic background (gender, ethnicity, and total household monthly income), anthropometry (body weight and height), and 7-day diet histories were collected. Secondary analysis was performed on dietary intakes to quantify food groups based on the Malaysian Dietary Guidelines and NOVA classification systems besides nutrients. Differences and associations between total monthly household income categories with anthropometry and dietary intakes were tested using independent *t*-test/Mann-Whitney U (depending on normality) and chi-square tests, respectively. **Results:** Most children in this study population had dietary intakes below the recommended serving sizes for five food groups, except meat/poultry (195.2±107.2%) and fish (110.1±106.3%) and consumed about 32% of energy from ultra-processed foods (NOVA food group 4). While there was no difference in dietary intake between the bottom 40% with the middle 40% and high 20% household income groups, the percentage of energy contributed by NOVA food group 4 (processed fats/oils, condiments, and sauces) was higher in the bottom 40% households ($p$=0.024). **Conclusion:** Most pre-adolescent children in this study, regardless of household income, did not meet dietary recommendations and ate diets comprised of less nutritious foods. Comprehensive approaches that aim to improve dietary patterns and reduce the risk of diet-related chronic diseases are warranted.

**Keywords:** children; dietary intake; income; Malaysian; NOVA group

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## INTRODUCTION

The exponential increase in the prevalence of non-communicable diseases and associated risk factors in developing countries is of concern (WHO, 2014). The negative implications of globalisation, rapid urbanisation, sedentary lifestyles, and poor dietary habits are evident and constitute considerable challenges. Studies have reported that rates of health risk factors showed patterns of considerable variability within the developing countries and may be unequally experienced by different socioeconomic groups (Magnusson, 2010). Populations that are socioeconomically disadvantaged tend to fare worse with regard to non-communicable diseases risk factor prevalence (WHO, 2014), though important exception exists where overweight and obesity remain concentrated in higher socioeconomic groups.

While socioeconomic status is a complex construct, income is only one of the possible indicators. Inadequate income, a frequently used indicator of lower socioeconomic status, puts individuals at risk of developing unhealthy dietary patterns that could contribute to inadequate or excess intakes of energy and nutrients, thus poorer diet quality (Darmon & Drewnowski, 2008). Studies on Western populations provide strong evidence of children from low-income households being more likely to have inadequate intakes of macro- and micronutrients (Kumanyika & Krebs-Smith, 2001). In contrast, a local nutrition survey found that more than 80% of these children consumed two main meals (lunch and dinner) and snacked significantly more than those of higher household income (Chong *et al.*, 2016). Hence, understanding the extent to which differences in dietary intakes are of concern can be fostered by examining how the intakes of the subpopulation groups compare to dietary guidelines.

The low diet quality among children from low-income populations has been closely associated with the consumption of low nutrient-dense foods that are high in cholesterol, saturated fat, added sugar, and sodium, as well as low in fibre (Mayen *et al.*, 2014), which are largely contributed by ultra-processed foods (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020; Monteiro *et al.*, 2019). Ultra-processed foods are characterised by foods or drinks formulated mostly or entirely from substances extracted from foods or derived from food constituents to make them highly convenient, attractive, and profitable. While such processes and ingredients can make ultra-processed foods nutritionally unbalanced and displace other types of foods (Monteiro *et al.*, 2019), there is emerging evidence that excluding ultra-processed foods may result in lowered intakes of key nutrients of particular concern for at-risk groups (Estell *et al.*, 2021). Ultra-processed foods are rapidly growing in middle-income countries (Baker & Friel, 2016) and contribute to almost half of the total dietary energy intake in some high-income country populations (Monteiro *et al.*, 2019).

Despite the risk of inadequate nutrition for low-income children, there is a paucity of literature on the extent of these nutritional issues, particularly in the Asian developing countries including Malaysia. Direct evidence on the dietary intake among Malaysian children from low-income families in urban communities is limited (Shariff *et al.*, 2015; Koo *et al.*, 2016; Yang *et al.*, 2017). Poor nutritional status increases health risk factors, which could be more prevalent amongst the lower-income group due to health and nutrition disparities. Hence, the purpose of this paper was to characterise dietary intakes by household income among Malaysian children in Kuala Lumpur.

## MATERIALS AND METHODS

This paper reports the secondary analysis of the baseline data from participants in the PREBONE-Kids Study, which was a 1-year randomised, double-blind, placebo-controlled trial of soluble corn fibre on bone indices in pre-pubertal children with ClinicalTrials.gov identifier: (NCT03864172). This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Research and Ethics Committee of the International Medical University (IMU R/2016). Written informed consent was obtained from all subjects, and assents were obtained from the children. The detailed protocol has been published elsewhere (Arasu *et al*., 2021) and is briefly explained here.

A total of 243 school children aged 9 to 11 years (127 boys and 116 girls) were recruited from March 2017 through March 2018. The study included participants who were healthy as determined by a standard medical assessment, at Tanner Stage 1 or 2 based on breast development for girls and pubic hair in boys, pre-menarcheal for girls, and able to provide assent. Participants were excluded if they had a history of serious medical conditions and received therapy with medications known to interfere with bone metabolism (e.g., steroids, hormones, diuretics, cortisone, or anti-seizure medication).

Participants' socio-demographic background was collected by interviewing their parents on gender, ethnicity, and total monthly household income. Household income was obtained as a range and subsequently reclassified based on the three broad national classifications of total monthly household income for urban areas (Department of Statistics, 2020). These are Bottom 40% (B40), Middle 40% (M40), and Top 20% (T20). The thresholds of the monthly household for each group refer to 1) B40: less than Ringgit Malaysia (RM) 4850; 2) M40: between RM4850 and RM10960; and 3) T20: RM10960 and above. The B40 household covers both poor and low-income groups.

Body weight and height were measured according to standard protocols using a calibrated weighing scale (TANITA HD-314, Tanita Corporation, Tokyo, Japan) and a portable stadiometer (SECA 213, SECA Group, Hamburg, Germany), respectively. Z-scores for body mass index (BMI)-for-age (5 to 19 years), weight-for-age (5 to 10 years), and height-for-age (5 to 19 years) were determined using the World Health Organization (WHO) AnthroPlus software (version 1.0.4, 2009 WHO Int, Geneva, Switzerland) (WHO, 2006). The interpretations of BMI z-score and height z-score were based on the WHO cut-offs to classify the participants into four BMI categories: thin (z-score $<-2.0$), normal (z-score $\geq-2.0$, $\leq1.0$), overweight (z-score $>1.0$, $\leq2.0$), and obese (z-score $>2.0$); and two height categories: stunting (z-score $<-2.0$) and normal (z-score $\geq -2.0$) (WHO, 2006).

Dietary intake data were collected using interviewer-administered 7-day diet histories assisted by household tools and a food photographs album. Participants were asked to recall their usual food and beverage intakes for breakfast, lunch, dinner, and snacks consumed, including the frequency of intake for these foods for a week (five school days and two weekend days). Standard training was provided to all enumerators before research commencement. The collected dietary assessment forms were counter-checked to ensure completeness and validity of reporting. The diet histories were further verified by randomly weighing the foods consumed at the school canteen and checking with participants' mothers whenever possible. The reported foods and beverages in the diet histories were converted into grams prior to analysis.

In determining serving sizes, foods and beverages obtained from the 7-day diet histories were classified into seven major food groups based on the Malaysian Dietary Guidelines (MDG)'s food pyramid (NCCFN, 2013): cereals; fruits; vegetables; meat/poultry; fish; legumes; milk and dairy products. The number of servings for these main food groups was calculated by aggregating the total amount for each food group and dividing it by the standard serving size from MDG. Subsequently, the number of daily servings consumed was compared to MDG recommendations for serving sizes (RSS). Using the similarities of the items' physical or preparation characteristics, nine sub-food groups were created: mixed dishes, sugar-sweetened beverages; western fast food; kuih/pastries/dessert; snacks; spread; sugar; oil and condiments. Mixed dishes were assigned a major food group based on primary ingredients, e.g., fried rice was assigned to 'cereals/tubers/grains'.

The individual mean daily nutrient intakes were analysed using Nutritionist Pro™ Diet Analysis software (Axxya Systems, Washington, United States of America), referencing against two national food composition databases from Malaysia (Tee *et al.*, 1997) and Singapore (Singapore HPB, 2003) due to similarities in food habits and cultures. Participants with implausible dietary intake were checked using a histogram plot on the distribution of energy intakes. Dietary outliers were defined as those with baseline energy intake >±2 standard deviations (*SD*) from mean energy intake of the population (Field *et al.*, 2004) and were removed from the final analysis. Total energy, macronutrients, and micronutrients intake values were compared with age-relevant nutrient recommendations; Estimated Average Requirement (EAR) by the National Academy of Medicine, USA (Food and Nutrition Board, Institute of Medicine, 2016) and Recommended Nutrient Intakes (RNI) 2017 for Malaysia (NCCFN, 2005).

Aside from the dietary adequacy perspective and given the lack of evidence on in-depth dietary patterns of Malaysian children, the Food and Agriculture Organization's NOVA classification system was subsequently used to characterise the participants' intakes. Foods and beverages were classified into four major groups: unprocessed or minimally processed foods (NOVA group 1), processed culinary ingredients (NOVA group 2), processed foods (NOVA group 3), and ultra-processed foods (NOVA group 4) (Monteiro *et al.*, 2019). The food description and ingredient list were obtained from the 7-day diet histories for assignment of a food or beverage into one of the four NOVA groups. The NOVA classification system was adapted to suit local variations in food preparation and food availability to improve accuracy (Table 1). For foods with a homemade recipe, the classification was applied to the underlying ingredients.

Data were tabulated using Microsoft Excel version 2016 (Microsoft Corporation, Redmond, Washington, USA). Analyses were carried out using IBM SPSS Statistics for Windows Version 27.0 (IBM Corp®, Armonk, New York, United States of America), and $p<0.05$ was considered statistically significant. Normality checking was done using the Shapiro-Wilk test, which results from skewness and kurtosis found the distributions to be normal for all variables, except for some micronutrients and food groups. Descriptive statistics were presented

**Table 1.** NOVA classification system adapted from the Food and Agriculture Organization

| *Food groups and subgroups* | *Descriptors* |
|---|---|
| **Unprocessed or minimally processed foods (NOVA group 1)** | |
| Meats, poultry, fish, and eggs | - |
| Milk and plain yoghurt | - |
| Fruits | - |
| Grains | Dry, raw, or cooked whole grain and bran of rice, oat, corn, wheat; white rice; pasta; and grain flour |
| Vegetables | - |
| Nuts, seeds, or legumes | - |
| Other | Dried fruits without added sugars, dried vegetables, non-flavoured coffee and tea, coconut water, and homemade soup |
| **Processed culinary ingredients (NOVA group 2)** | |
| Plant oils | - |
| Animal fats | Butter and ghee |
| Sugar | Brown, granulated, or powdered sugar and honey added when cooking unprocessed or minimally processed foods at home/ restaurants |
| **Processed foods (NOVA group 3)** | |
| Cheese | - |
| Canned, smoked, or cured meats and fish | - |
| Canned fruits and vegetables | - |
| Rice-based dishes | Rice-based dishes such as oil rice, coconut milk rice, fried rice, fried noodles, and noodles soup |
| Meats, poultry, fish, and eggs-based dishes | Meats, poultry, fish, and eggs-based dishes such as sambal chicken, braised chicken with soya sauce, *ayam masak merah*, braised fish in tamarind sauce, and sambal cuttlefish/prawn |
| Other | Salted or sugared nuts and seeds |
| **Ultra-processed foods (NOVA group 4)** | |
| Industrial grain foods | Breads, rolls; breakfast cereals; biscuits, muffins, and quick breads; and pancakes, waffles, and French toast |
| Ready-to-heat and -eat mixed dishes | Pizza; sandwiches or hamburgers; and other mixed dishes that are ready-to-eat or ready-to-heat |
| Sweet snacks and sweets | Sweet bakery products (cakes, cookies, pies, and pastries); ice cream and desserts (ice pops, pudding, and fruit); candy |
| Savory snacks | Crackers, chips, and popcorn |
| Fast food or reconstituted meat, poultry, or fish | Meat patties, fried chicken, fish sticks, patties, or fillets; chicken nuggets, sausages, ham, and luncheon meats; and beef or other types of jerky |
| Sugar-sweetened beverages | Sugar-sweetened and diet soft drinks; fruit and other sweetened drinks (e.g., cordial) |
| Processed fats or oils, condiments, and sauces | Dressing, gravy, dips, spreads, mustard, margarine, and industrial fats |
| Flavoured dairy foods and substitutes | Flavoured milk, flavored yoghurt, milk shakes, and other dairy drinks |
| Fast food or prepared potato products | French fries, hash browns, potato puffs, and stuffed potatoes |
| Other | Soy products such as meatless patties; and distilled alcoholic drinks |

**Table 2.** Characteristics of the children (*N*=230)

| | *Total (N=230)* | *B40 (n=180)* | *Non-B40 (n=50)* | *p-value* |
|---|---|---|---|---|
| Age (years), mean±*SD* | 10.1±1.0 | 10.0±1.0 | 10.1±0.9 | 0.614 |
| Gender, *n* (%) | | | | |
| Boys | 120 (52.2) | 96 (80.0) | 24 (20.0) | 0.504 |
| Girls | 110 (47.8) | 84 (76.4) | 26 (23.6) | |
| Ethnicity, *n* (%) | | | | |
| Malay | 209 (90.9) | 162 (77.5) | 47 (22.5) | 0.579 |
| Indian | 21 (9.1) | 18 (85.7) | 3 (14.3) | |
| Monthly household income category, *n* (%) | | | | |
| Bottom 40 (B40) | 180 (78.3) | NA | NA | NA |
| Middle 40 (M40) | 37 (16.1) | NA | NA | NA |
| Top 20 (T20) | 13 (5.7) | NA | NA | NA |
| Anthropometry, mean±*SD* | | | | |
| Weight (kg) | 33.7±12.0 | 33.1±11.4 | 35.8±13.9 | 0.161 |
| Height (cm) | 135.6±9.1 | 135.1±9.0 | 137.5±9.6 | 0.094 |
| BMI-for-age (kg/m$^2$) | 17.9±4.4 | 17.8±4.3 | 18.5±4.8 | 0.339 |
| BMI-for-age z-score | 0.2±1.7 | 0.1±1.7 | 0.3±1.7 | 0.413 |
| Weight-for-age z-score[a] | -0.3±1.6 | -0.3±1.7 | -0.3±1.4 | 0.898 |
| Anthropometry, *n* (%) | | | | |
| BMI *z*-score classification | | | | |
| Thinness | 19 (8.3) | 14 (7.8) | 5 (10.0) | 0.862 |
| Normal | 136 (59.1) | 109 (60.6) | 27 (54.0) | |
| Overweight | 37 (16.1) | 28 (15.6) | 9 (18.0) | |
| Obese | 38 (16.5) | 29 (16.1) | 9 (18.0) | |
| Height *z*-score classification | | | | |
| Normal | 206 (89.6) | 161 (89.4) | 45 (90.0) | 0.909 |
| Stunting | 24 (10.4) | 19 (10.6) | 5 (10.0) | |
| Percentage of intake compared to RSS (%), mean±*SD*[b] | | | | |
| Cereals/tubers/grains | 70.4±24.7 | 70.9±25.5 | 68.6±21.7 | 0.561 |
| Fruits[d] | 0.0±6.5 | 0.0±4.6 | 0.0±19.1 | 0.070 |
| Vegetables[d] | 53.7 (148.7) | 44.8 (125.5) | 108.5 (165.1) | 0.014* |
| Meat/poultry | 195.2±107.2 | 197.9±110.4 | 185.6±95.4 | 0.476 |
| Fish | 110.1±106.3 | 110.0±110.0 | 110.4±92.8 | 0.978 |
| Legumes[d] | 0.0±6.0 | 0.0±6.0 | 0.0±8.5 | 0.180 |
| Milk & dairy products | 8.6±15.5 | 7.8±14.6 | 11.6±18.2 | 0.174 |
| Number of children below RSS, *n* (%)[c] | | | | |
| Cereals/tubers/grains | 196 (85.2) | 152 (84.4) | 44 (88.0) | 0.531 |
| Fruits | 227 (98.7) | 179 (99.4) | 50 (100.0) | 1.000 |
| Vegetables | 146 (63.5) | 117 (65.0) | 29 (58.0) | 0.363 |
| Meat/poultry | 32 (13.9) | 25 (13.9) | 7 (14.0) | 0.984 |
| Fish | 127 (55.2) | 103 (57.2) | 24 (48.0) | 0.246 |
| Legumes | 224 (97.4) | 177 (98.3) | 47 (94.0) | 0.119 |
| Milk & dairy products | 230 (100.0) | 180 (100.0) | 50 (100.0) | NA |

NA: not applicable; SD: standard deviation; RSS: recommended serving size; B40: less than RM 4850; M40: between RM4850 and RM10960; T20: RM10960 and above

[a]*n*=109 as z-scores for 5 to 10 years

[b]Independent *t*-test

[c]Chi-Square/Fisher's exact test

[d]Median (inter-quartile range) tested with Mann-Whitney U test

*$p<0.05$

as frequencies and percentages for categorical variables, and mean and *SD*s, or median and interquartile range for continuous variables.

For comparisons by total monthly household income, the household income of M40 and T20 were re-categorised into non-B40 (effect size, d=0.45) (Kang, 2015). Associations between total monthly household income categories with anthropometry, food groups, and nutrients were tested using parametric tests. Comparisons with recommendations (RSS, EAR, and RNI) and NOVA classification by total monthly household income, body weight status, and gender categories were completed using independent *t*-tests/Mann-Whitney tests/ analysis of variance tests (continuous variables) and chi-squared tests (categorical variables).

## RESULTS

Of the 243 children enrolled at baseline, individuals with implausible dietary intakes (*n*=4) and missing data for household income (*n*=9) were excluded from this analysis. This resulted in a sample of 230 children for secondary

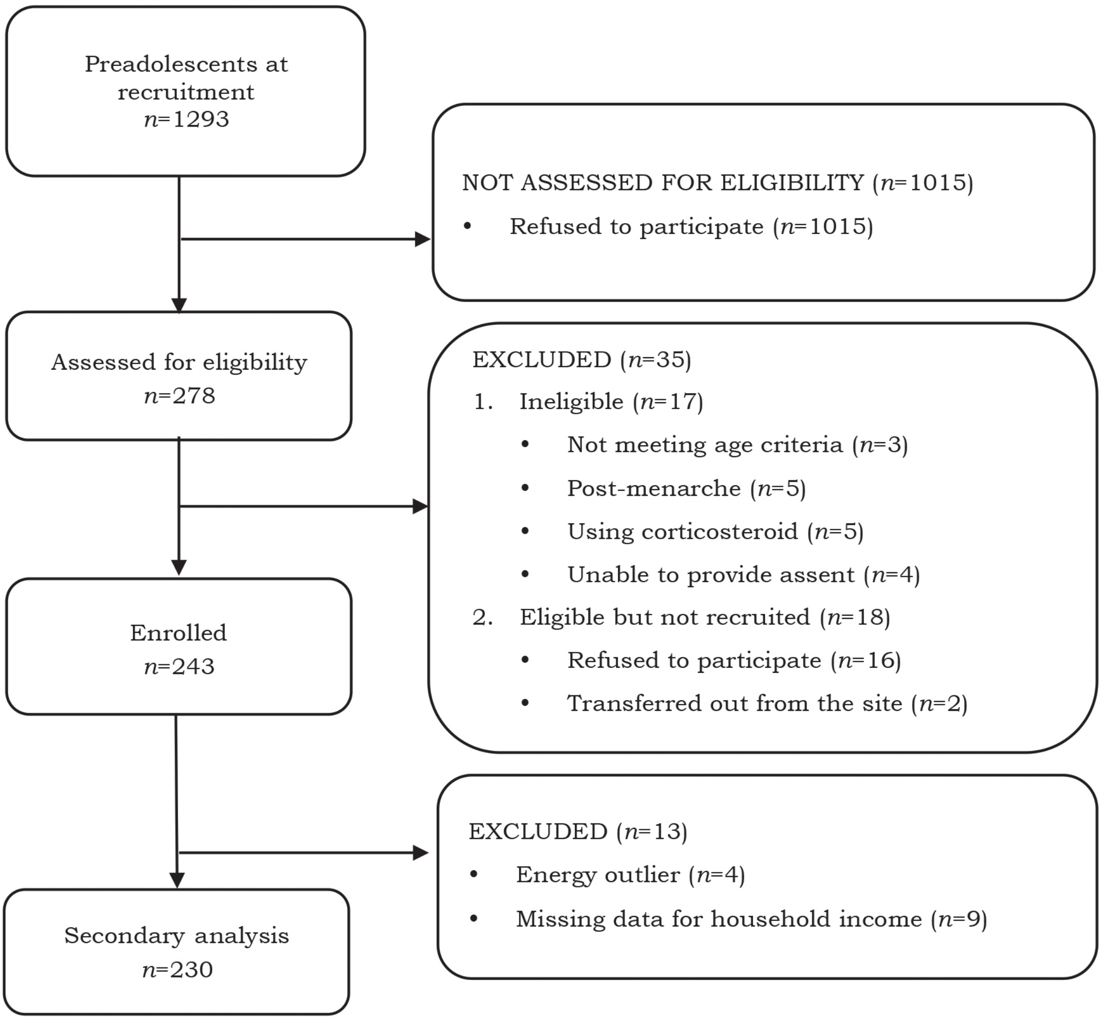


**Figure 1.** Flow chart of participants included in a secondary analysis

analysis (Figure 1). Table 2 describes the characteristics of all children including socio-demography, anthropometry, and dietary intakes. The children's mean age was 10.1±1.0 years, with equal gender distribution. Malay ethnicity was predominant (90.9%). Based on the national classification of total monthly household income, 78.3% of families reported a total household monthly income within the B40 household, and only 5.7% were in the T20 households.

Table 3 shows the estimated percentages of energy from NOVA food groups. The percentages of energy from the subgroup of processed fats/oils, condiments, and sauces in NOVA food group 4 were higher in B40 households (2.8±3.4% vs. 1.7±1.8%, $p$=0.024). In the NOVA food groups analyses, some subgroups showed a trend of non-B40 having higher intakes of processed food groups than B40 households. This included the unprocessed or minimally processed foods (NOVA food group 1), such as milk, plain yoghurt, and grains; and sugar (NOVA food group 2). Overall, all children from both households had high percentages of energy from ultra-processed foods (NOVA food group 4), with a total of 33.3±12.9% for non-B40 vs. 31.4±14.5% for B40 group; with more than half contributed by industrial grain foods (5.5%), ready-to-heat and ready-to-eat mixed dishes (6.8%), and sugar-sweetened beverages (5.7%). Additional analyses on ultra-processed foods (NOVA food group 4) by body weight status and gender did not show any statistical differences ($p$>0.05).

As shown in Table 4, dietary intakes were presented as nutrients, in which all children in this study had reported poor mean intakes for calcium, potassium, vitamin C, and vitamin D. There were no significant differences for all nutrients between children from B40 and non-B40 households. When comparing with nutrient recommendations (EAR and RNI), the percentages of intake achieving EAR were higher than RNI in this sample for both households. Those nutrients with percentages of intake that exceeded the EAR were carbohydrates, protein, iron, and vitamin A, while only protein and sodium intakes were above RNI. Children from B40 households had significantly higher percentage of intake meeting RNI for phosphorus (58.8 ±46.0% RNI vs. 55.3 ±24.9% RNI, $p$=0.049).

All or most children, regardless of their household income, had intakes below both nutrient recommendations (EAR and RNI) for calcium and vitamin D. In contrast, only four children were not able to meet their protein requirement based on RNI, mainly from non-B40 households (6.0% vs. 0.6%, $p$=0.033). Other nutrients including energy, vitamin C, and thiamine followed a similar trend of intake below recommendations amongst the non-B40, but these did not achieve statistical significance.

## DISCUSSION

The secondary analysis of the PREBONE-Kids study aimed to characterise dietary intakes by total household income among a sample of Malaysian children in Kuala Lumpur. Results from the present study extend previous studies (Shariff *et al.*, 2015; Yang *et al.*, 2017) by describing dietary intakes in terms of food groups (including the NOVA classification system) and nutrients of children aged between 9 and 11 years, and comparing the differences between two levels of household income. The main findings accepted the null hypothesis that there was no difference in dietary quality between low-income and higher-income households. Irrespective of household income, most children had dietary intakes below the recommendations and consumed 32% of energy from ultra-processed foods, with a relatively high

**Table 3.** Estimated percentage of energy from NOVA classification system by household income

| *Food groups and subgroups* | *Estimated % of energy from consumption of foods by household income, mean±SD* | | | *p-value* | *Mean difference (95% CI)* |
|---|---|---|---|---|---|
| | *Total (N=230)* | *B40 (n=180)* | *Non-B40 (n=50)* | | |
| Unprocessed or minimally processed foods (NOVA group 1) | | | | | |
| Total | 33.9±13.5 | 34.3±13.6 | 32.5±13.0 | 0.416 | 1.76 (-2.50 to 6.01) |
| Meats, poultry, fish, and eggs | 14.5±8.5 | 14.7±8.5 | 13.6±8.6 | 0.406 | 1.13 (-1.55 to 3.81) |
| Milk and plain yoghurt | 1.0±2.5 | 1.2±2.7 | 0.6±1.6 | 0.058 | 0.58 (-0.02 to 1.17) |
| Fruits | 0.8±1.9 | 0.8±2.0 | 0.9±1.7 | 0.751 | -0.10 (-0.71 to 0.51) |
| Grains | 16.3±8.2 | 16.3±8.3 | 16.1±7.5 | 0.823 | 0.29 (-2.28 to 2.87) |
| Vegetables | 1.0±1.6 | 1.0±1.6 | 1.0±1.4 | 0.885 | -0.04 (-0.54 to 0.47) |
| Nuts, seeds or legumes | 0.1±0.5 | 0.1±0.5 | 0.0±0.2 | 0.368 | 0.07 (-0.08 to 0.21) |
| Other | 0.3±0.7 | 0.2±0.5 | 0.4±1.1 | 0.269 | -0.18 (-0.50 to 0.14) |
| Processed culinary ingredients (NOVA group 2) | | | | | |
| Total | 6.2±4.7 | 6.4±4.8 | 5.6±3.9 | 0.314 | 0.75 (-0.72 to 2.22) |
| Plant oils | 3.8±3.4 | 3.8±3.4 | 3.9±3.2 | 0.873 | -0.09 (-1.15 to 0.98) |
| Animal fats | 0.2±0.6 | 0.2±0.6 | 0.1±0.4 | 0.691 | 0.04 (-0.14 to 0.21) |
| Sugar | 2.2±3.5 | 2.4±3.8 | 1.6±2.3 | 0.158 | 0.80 (-0.31 to 1.91) |
| Processed foods (NOVA group 3) | | | | | |
| Total | 28.1±12.8 | 27.9±12.5 | 28.5±13.9 | 0.775 | -0.59 (-4.63 to 3.46) |
| Cheese | 0.2±0.8 | 0.2±0.8 | 0.2±0.8 | 0.750 | -0.04 (-0.29 to 0.21) |
| Canned, smoked, or cured meats and fish | 0.4±1.1 | 0.4±1.1 | 0.4±0.8 | 0.660 | 0.07 (-0.25 to 0.41) |
| Canned fruits and vegetables | 0.0±0.0 | 0.0±0.0 | 0.0±0.0 | 0.599 | 0.00 (-0.009 to 0.01) |
| Rice-based dishes | 19.6±11.6 | 19.6±11.6 | 19.4±11.8 | 0.891 | 0.25 (-3.41 to 3.91) |
| Meats, poultry, fish, and eggs-based dishes | 7.7±6.1 | 7.5±6.0 | 8.5±6.6 | 0.328 | -0.96 (-2.88 to 0.97) |
| Other | 0.3±1.0 | 0.3±1.1 | 0.2±0.8 | 0.627 | 0.09 (-0.24 to 0.40) |
| Ultra-processed foods (NOVA group 4) | | | | | |
| Total | 31.8±14.2 | 31.4±14.5 | 33.3±12.9 | 0.397 | -1.92 (-6.39 to 2.54) |
| Industrial grain foods | 5.5±6.1 | 5.4±6.0 | 6.0±6.5 | 0.522 | -0.63 (-2.54 to 1.30) |
| Ready-to-heat and -eat mixed dishes | 6.8±7.4 | 6.8±7.7 | 6.8±6.4 | 0.992 | -0.01 (-2.34 to 2.32) |
| Sweet snacks and sweets | 2.9±5.4 | 2.7±5.0 | 4.0±6.5 | 0.129 | -1.30 (-2.99 to 0.38) |
| Savoury snacks | 2.6±5.4 | 2.3±4.8 | 3.8±7.2 | 0.174 | -1.49 (-3.64 to 0.67) |
| Fast food or reconstituted meat, poultry, or fish | 3.0±4.7 | 3.0±4.9 | 3.1±4.0 | 0.938 | -0.06 (-1.56 to 1.44) |
| Sugar-sweetened beverages | 5.7±4.6 | 5.8±4.8 | 5.3±3.8 | 0.456 | 0.55 (-0.90 to 2.00) |
| Processed fats or oils, condiments, and sauces | 2.6±3.2 | 2.8±3.4 | 1.7±1.8 | 0.024* | 1.15 (0.15 to 2.15) |
| Flavoured dairy foods and substitutes | 0.7±2.0 | 0.7±2.1 | 0.5±1.2 | 0.438 | 0.24 (-0.37 to 0.86) |
| Fast food or prepared potato products | 1.9±3.4 | 1.8±3.4 | 1.7±1.8 | 0.518 | -0.35 (-1.43 to 0.73) |
| Other | 0.1±0.5 | 0.1±0.4 | 0.1±0.6 | 0.751 | -0.02 (-0.17 to 0.12) |

*SD*: standard deviation; B40: less than Ringgit Malaysia (RM)4850; non B40: RM4850 and above
*$p$<0.05 tested with independent $t$-test

**Table 4.** Dietary intakes of children compared with the National Academy of Medicine's estimated average requirement (EAR) and Malaysian recommended nutrient intake (RNI) by household income

| Nutrients | USA NAM EAR | Malaysian RNI | *Intakes, mean±SD* | | *% of USA NAM EAR, mean±SD* | | *% of Malaysian RNI, mean±SD* | | *No. Children < USA NAM, n (%)* | | *No. Children < Malaysian RNI, n (%)* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *B40 (n=180)* | *Non- B40 (n=50)* | *B40 (n=180)* | *Non- B40 (n=50)* | *B40 (n=180)* | *Non- B40 (n=50)* | *B40 (n=180)* | *Non- B40 (n=50)* | *B40 (n=180)* | *Non- B40 (n=50)* |
| Energy (kcal) | NA | 1607 | 1421±376 | 1403±360 | NA | NA | 92.1±24.0 | 91.4±24.4 | NA | NA | 103 (57.2) | 31 (62.0) |
| Carbohydrates (g) | 100 | NA | 173.6±53.2 | 170.8±49.9 | 174.8±54.2 | 166.8±45.3 | NA | NA | 10 (5.5) | 3 (6.0) | NA | NA |
| Protein (g) | 0.76[b] | 32.5 | 59.4±18.0 | 59.7±17.0 | 233.5±69.9 | 228.1±68.1 | 223.5±75.6 | 225.0±79.9 | 1 (0.6) | 1 (2.0) | 1 (0.6)* | 3 (6.0)* |
| Fats (g) | NA | NA | 54.8±16.6 | 53.3±15.7 | NA | NA | NA | NA | NA | NA | NA | NA |
| Sodium (mg) | NA | 1500 | 1999±709 | 1971±647 | NA | NA | 141.3±54.0 | 130.9±45.7 | NA | NA | 35 (19.4) | 15 (30.0) |
| Potassium (g) | NA | 4500 | 840.0±310.2 | 806.2±268.2 | NA | NA | 19.3±7.3 | 18.1±6.2 | NA | NA | 180 (100.0) | 50 (100.0) |
| Phosphorus (mg) | 1055 | 1250 | 644±329[a] | 690±304[a] | 61.4±30.8[a] | 62.7±31.5[a] | 58.8±46.0[a,*] | 55.3±24.9[a,*] | 164 (91.1) | 48 (96.0) | 173 (96.1) | 48 (96.0) |
| Calcium (mg) | 1100 | 1200 | 345.0±182.7 | 328.7±146.2 | 31.9±16.7 | 28.2±12.4 | 30.5±17.4 | 28.3±13.9 | 180 (100.0) | 50 (100.0) | 179 (99.4) | 50 (100.0) |
| Iron (mg) | 5.8 | 12.7 | 11.3±5.6 | 11.6±5.4 | 225.1±173.0 | 220.3±174.6 | 96.4±66.0 | 94.5±55.0 | 10 (5.5) | 6 (12.0) | 89 (49.4) | 25 (50.0) |
| Vitamin C (mg) | 39 | 55 | 17.7±28.0[a] | 21.1±47.0[a] | 45.3±71.8[a] | 54.0±77.1[a] | 35.9±56.9[a] | 37.0±49.8[a] | 140 (77.8) | 38 (76.0) | 142 (78.9) | 44 (88.0) |
| Vitamin D (μg) | 10 | 15 | 1.5±1.6 | 1.2±1.1 | 15.0±16.5 | 12.2±10.7 | 10.1±11.0 | 8.0±7.3 | 180 (100.0) | 50 (100.0) | 180 (100.0) | 50 (100.0) |
| Vitamin A (μg) | 433 | 568 | 459.7±262.9 | 487.6±261.9 | 106.6±59.8 | 111.0±63.7 | 83.4±48.1 | 89.2±51.6 | 99 (55.0) | 27 (54.0) | 129 (71.7) | 34 (68.0) |
| Thiamine (mg) | 0.7 | 1.1 | 0.6±0.3 | 0.6±0.2 | 85.9±41.5 | 81.2±32.5 | 58.7±30.0 | 55.3±22.3 | 134 (74.4) | 40 (80.0) | 157 (87.2) | 47 (94.0) |
| Riboflavin (mg) | 0.8 | 1.1 | 0.7±0.5[a] | 0.8±0.5[a] | 83.8±60.7[a] | 95.9±76.7[a] | 65.6±48.8[a] | 74.6±45.5[a] | 115 (63.9) | 26 (52.0) | 138 (76.7) | 37 (74.0) |
| Niacin (mg) | 9.0 | 14.7 | 6.0±4.4[a] | 6.3±4.2[a] | 66.4±48.4[a] | 70.8±46.9[a] | 41.7±36.6[a] | 44.1±26.7[a] | 139 (77.2) | 38 (76.0) | 170 (94.4) | 49 (98.0) |

USA NAM: United States of America's National Academy of Medicine; EAR: estimated average requirement; RNI: recommended nutrient intake; SD: standard deviation; NA: not available; B40: less than RM4850; Non-B40: RM4850 and above)

[a] expressed as median (inter-quartile range) tested with Mann-Whitney U test

[b] expressed as g/kg/day (calculated by mean weight; [*]$p$<0.05

prevalence of stunting (10.4%) and more than 30% of overweight and obesity in this population.

At present, evidence on the prevalence of stunting is mixed within studies from Malaysia depending on the location and age group of comparison (Chong *et al*., 2016). Stunting is an indication of chronic malnutrition reflecting the cumulative effects of undernutrition and infections, and is associated with delayed mental development and reduced intellectual capacity (WHO, 2006). On the other hand, results on body weight categories were consistent with local studies (Chong *et al*., 2016; Yang *et al*., 2017) and similar to those reported from high-income countries globally (González-Álvarez *et al*., 2020). Childhood obesity and stunting are major risk factors of poor health and early death due to chronic diseases (WHO, 2006). In the context of the co-existence of the triple burden of malnutrition and from the perspective of meeting nutrient needs, the available evidence suggests that the entire children population could benefit from positive changes in dietary intakes.

The percentages of energy from ultra-processed foods found in this study (about 32%) is consistent with the literature for children; much lower than the US and United Kingdom (>50%), but higher than Italy (about 10%) (Monteiro *et al*., 2019; Estell *et al*., 2021). Specifically, the dietary share of ultra-processed foods was associated with a deranged nutrient profile including excessive consumption of sodium and a lower intake of calcium, potassium, phosphorus, vitamins C and D, thiamine, riboflavin, and niacin. The observed effects between the intake of ultra-processed foods and dietary intakes are in agreement with the evidence available since the concept of ultra-processed foods was first introduced in 2009 (Monteiro *et al*., 2019). A recent systematic review of worldwide consumption of ultra-processed foods concluded high variability in the intake, with young people, men, and overweight/obese generally having higher levels of consumption (Marino *et al*., 2021). Taken together, the results of relatively high percentages of ultra-processed food intake and its dietary share within the children's dietary intake may suggest the potential of increased non-communicable disease risk development amongst children to be further explored in future studies (WHO, 2014; Magnusson, 2010).

In-depth analyses using the NOVA classification system highlighted the contribution of processed grains to the pre-adolescents' dietary intakes irrespective of income status in this study. A NOVA system states that ultra-processed foods contain additives that automatically include the majority of processed grains such as fortified ready-to-eat breakfast cereal or whole wheat bread (Monteiro *et al*., 2019). Hence, healthful nutrients or other beneficial elements like whole grains and dietary fibre are not represented in a person's diet. A secondary analysis using dietary modelling on grain foods consumed in a national nutrition survey discovered the potential for altered nutrient intakes (thiamine, folate, iron, and iodine) while avoiding ultra-processed foods and replacing them with minimally processed foods (Estell *et al*., 2021). This emerging evidence predicts similar outcomes in other countries with fortification programmes and suggests that the NOVA system should be used cautiously (Estell *et al*., 2021).

The differences in consumption of processed fats or oils, condiments, and sauces within the ultra-processed food group among children from different incomes in this study reflected the global pattern in the nutrition transition stage. Countries in Latin America have demonstrated that those from the highest income group consumed more ultra-processed foods (Marrón-Ponce *et al.*, 2018), while in developed countries, such as the United Kingdom, France, and United States, the opposite trend was observed (Monteiro *et al.*, 2019; Estell *et al.*, 2021). Although ultra-processed foods are rapidly growing in middle-income countries (Baker & Friel, 2016), these foods are considerably more expensive than fresh or minimally processed foods, hence higher-income households with higher purchasing ability are able to afford these types of foods, whereas, this might not be the case in high-income countries (Moubarac *et al.*, 2013). At present, Malaysia is in the upper middle-income group, modelling similar situation as high-income countries that warrants further attention (Department of Statistics, 2020).

Most children in this study had fewer than the recommended five servings of fruits and vegetables, coupled with low vitamin C and potassium intakes. Findings from nutrition surveys in Malaysia provided little evidence to conclude that socioeconomic status was associated with children's fruits and vegetables consumption (Shariff *et al.*, 2015; Yang *et al.*, 2017). Despite not meeting the national recommendations for fruits and vegetables, the common sources of fruits were watermelon as it was sold in the school canteen, while non-green leafy vegetables were more popular than green leafy vegetables. The poor intake of fruits and vegetables among children might be a result of a combination of factors such as taste, habit, social influences, and availability. Research has shown differential sensitivity to prices of fruits and vegetables across income, suggesting that changing food prices may be a viable strategy for influencing dietary quality (Beydoun & Wang, 2008).

This is one of the few studies in Malaysia to characterise dietary intakes, including the NOVA classification system, among children living in urban Kuala Lumpur. The strength of this study is the comprehensive method of dietary data collection with verification by mothers and weighing of foods sold in school canteens to obtain a more accurate assessment of dietary intakes. Nevertheless, the 7-day diet history has its limitations on participants' bias including recording and recalling. The study, however, collected data from predominantly Malay children from low-income households, which could limit the generalisability of the results. Data on specific children receiving the supplementary food programme (*Rancangan Makanan Tambahan*) at school is lacking; hence, we were unable to differentiate the source of foods to understand the ability of the governmental programme in promoting diet quality amongst low-income households. If the differences in diet quality were a result of the foods served either at school or home, then specific strategies can be directed to increase nutrition awareness and improve the nutritional intake of children. The application of the NOVA classification system itself has limitations as it may not truly consider the nutritional values of commercially prepared foods.

## CONCLUSION

Overall, children from the PREBONE-Kids study residing in urban Kuala Lumpur were experiencing a double burden of both malnutrition and overweight with diets comprised of less nutritious foods. Most children did not meet the national and international dietary recommendations, regardless of their household income, indicating the need for continued efforts to improve the dietary patterns of this population as a whole. Without a comprehensive approach, individual- and environmental-level initiatives that aim to improve dietary patterns and reduce the risk of obesity or other micronutrient deficiencies diet-related chronic diseases, may not be effective but could potentially exacerbate disparities.

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**Authors' contributions**

Yang WY, conceptualised the manuscript, contributed to the investigation, conducted the formal analysis and data curation, and prepared the original draft of the manuscript; Wong SY, contributed to the investigation, conducted the formal analysis and data curation, and reviewed and edited the manuscript; Ong SH, Arasu K, and Chang, contributed to the investigation and data curation, reviewed and edited the manuscript; Chong MHZ, Meenal M, and Khoo EJ, contributed to the investigation and reviewed and edited the manuscript; Weaver CM, conceptualised, reviewed and edited the manuscript; Chee WSS, principal investigator, contributed to the methodology, supervision, project administration, funding acquisition, conceptualised the manuscript, and contributed to the review and editing of the manuscript. All authors read and approved the final version of the manuscript.

**Conflict of interest**

The authors declare that there is no conflict of interest. The sponsoring body had no role in the study design, implementation, outcome, and publication of the study.

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